APPENDIX B

CONTROL LOGIC DIAGRAM (CLD) TUTORIAL

B-1 INTRODUCTION

The control logic diagram (CLD) is an unambiguous graphical description of the control system sequence of operation. The focus of the CLD is on control logic, not on a particular hardware implementation. In particular, the CLD does not distinguish between normally open or normally closed contacts, valves, or dampers; these details should instead be indicated on the appropriate wiring diagram, valve/damper schedule, or control schematic drawing. The CLD is concerned with whether a given signal is TRUE or FALSE.

For example, a typical sequence calls for a ‘fan status’ input (to be used in a fan-proof logic block). The actual hardware could be implemented in a variety of ways, -- a current-sensing-relay on the fan motor, a DP switch across the fan, or an air flow proof switch. The actual hardware used is irrelevant to the CLD. Any one of these possible hardware devices would be shown as a simple binary input to the sequence. Another example would be the freeze stat (CooLinG-Discharge-Air-Temp-LowLimit; CLG-DA-T-LL) which is TRUE when the freeze stat trips; whether that’s from a set of NO or NC contacts is a detail for the wiring diagram. Finally, the Controller hardware implementation is not shown; while a given functional block is probably implemented in one controller, a build-up system (such as a RF VAV system with MA Economizer and Ventilation Demand control) may be in one or more controllers – the CLD does not make that distinction.

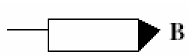
B-2 FUNCTIONAL BLOCKS USED IN CONTROL LOGIC DIAGRAMS

In the following descriptions, logical values are always referred to as TRUE or FALSE. Synonyms for these names include ON and OFF, as well as 1 and 0.

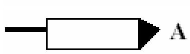
B-2.1 Signal


This line represents a signal path within the logic, either analog or binary. This line will be used on other blocks to show signal inputs and/or outputs.

B-2.2 Actuator Output



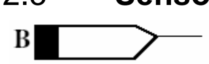
2-Position Actuator Output



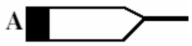
Modulating Actuator Output

This block represent a physical output from the system, an actuator or valve. It takes a binary or analog input and drives a piece of hardware. Since the CLD shows the control logic without reference to the hardware implementation, the actual hardware is unspecified.

B-2.3 Sensor Input



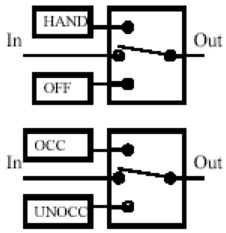
Binary Sensor Input



Analog Sensor Input

This block represents a hardware sensor input to the system. It may provide either an analog or binary signal. Again, the exact hardware type is unspecified.

B-2.4 **Hand-Off-Auto (H-O-A) Switch**



H-O-A Switch

This represents a HAND-OFF-AUTO switch. Sometimes, a H-O-A switch will be shown differently; for example where the position of the H-O-A switch would select some input to control logic. This block is generally used when the output of a control block is selected. The top block shows a normal H-O-A switch, the bottom shows a variant where the manually selected values are OCCUPIED or UNOCCUPIED.

B-2.5 **Constant Value**

Binary Constant Value

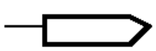
Analog Constant Value

This logic block represents a constant value, either analog or binary

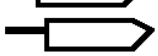
B-2.6 **Signal I/O**

Binary Signal Input

Analog Signal Input



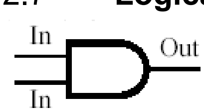
Binary Signal Output



Analog Signal Output

This block represents a named signal path within the logic. This is functionally identical to the **Signal** symbols described earlier, except that this signal is given a name, which allows it to be defined or used elsewhere in the logic.

B-2.7 **Logical AND**



Logical AND Function

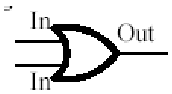
This logic block represents the logical AND function. It takes two or more binary inputs and produces a binary output. Its output is TRUE if and only if all of its inputs are TRUE. If any of its inputs are FALSE, then its output is FALSE.

B-2.8 **Logical NOT**

Logical NOT Function

This logic block represents the logical NOT function. It has one binary input and one binary output. Its output is TRUE if and only if its input is FALSE. If its input is TRUE, its output is FALSE.

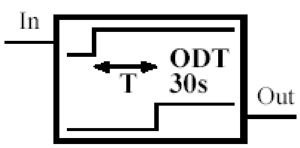
B-2.9 **Logical OR**



Logical OR Function

This logic block represents the logical OR function. It has two or more binary inputs and one binary output. Its output is TRUE if and only if any of the inputs are true. If all the inputs are FALSE, the output is FALSE.

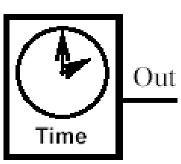
B-2.10 **On Delay Timer**



On Delay Timer

This logic block represents an On Delay Timer. It has one binary input and one binary output. In addition it has one parameter, a time (T) value. The output is always equal to the input, except when the input changes value from FALSE to TRUE. In this case, the transisition of the output from FALSE to TRUE is delayed by the value of the time parameter. This time value has no effect on the transistion from TRUE to FALSE, it only affects the output when the input becomes TRUE.

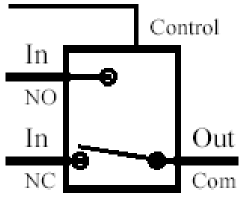
B-2.11 **Sequencer**



Sequencer

This block represents a sequencer, such as a scheduler or time clock. It provides one or more outputs. The outputs are typically binary values; however they may be enumerated values (sometimes incorrectly referred to as digital outputs), where the output may assume multiple discrete integer values (i.e. 0, 1, 2, 3, …, but not floating point values like 2.5). The output will not be an analog value.

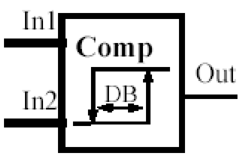
B-2.12 **Switch**



Switch

This block represents an analog switch with 2 analog inputs, one analog output, and a binary control input. When the control input is false, the output is the value of the analog signal at the Normally Closed (NC) input. When the control input is true, the output is the value of the analog signal at the NO (Normally Open) input. Note that this convention for NC and NO follows the electrical switch convention; it is opposite from that used for pneumatic switches.

B-2.13 **Comparator with Deadband**



Comparator with Deadband

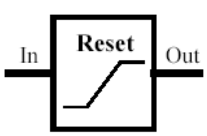
This logic block represents a comparator function with hysteresis. It takes two analog inputs and produces a binary output. It also has one parameter, deadband (DB). As shown in Table C-1 the output value only changes if the difference between the inputs exceeds half the deadband, if the difference in inputs is less than half the deadband, the output remains at its present value.

Table C-1. Comparator Input and Corresponding Output

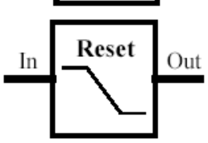
Input Conditions	Output Value
(*In1–In2*) < -*deadband*/2	FALSE
-*deadband*/2 ≤ (*In1–In2*) ≤ *deadband*/2	Output does not change; remains fixed
(*In1–In2*) > +*deadband*/2	TRUE

For example, if *In1*=75, *In2*=68 and the *deadband*=4, the output would be TRUE. As *In1* fell, the output would remain TRUE until *In1* went below 66 (68–66=4/2). Essentially, the output of this block is TRUE if the top value is greater than the bottom value and FALSE if the bottom value is greater than the top value (neglecting the deadband).

B-2.14 **Reset Schedule**



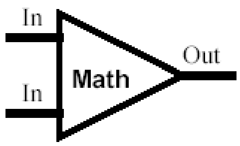
Reset Schedule
(output increases as input increases)



Reset Schedule
(output decreases as input increases)

This block represents a reset schedule. It has one analog input, one analog output, and 4 parameters: InputMin, InputMax, OutputMin, and OutputMax. For the first reset schedule shown, the output increases as the input increases; as the input ranges from InputMin to InputMax, the output varies linearly from OutputMin to OutputMax. Inputs below InputMin or above InputMax result in the output going to OutputMin or OutputMax, respectively. For the second reset schedule shown, the output decreases as the input increases. The reset schedule block can be thought of as a graph, with the input variable on the X-axis and the output variable on the Y-axis.

B-2.15 **Math Function**



Math Function

This logic block represents a variety of mathematical functions. It takes two or more analog inputs and produces an analog output. Some common functions for this block are shown in Table C-2.

Table C-2. Common Math Block Functions

Name	Function
Minus	Subtraction
Minimum	Select the minimum value from the input values
Maximum	Select the maximum value from the input values
Plus	Addition

B-2.16 **PID Loop with Enable**

Picture not available at this time

PID Loop with Enable and Default Output

This function block represents a PID loop with an Enable input. It has 2 analog inputs (a value and a setpoint), an analog output, a binary ENABLE input, and several parameters as described in

Table C-3. PID Block Parameters

Parameter	Description
Default	Value of output when Enable = FALSE

B-2.16.1 **IF Block**

Picture not available at this time

The IF Block is TRUE if the input meets the condition inside the block, otherwise the IF Block's output is FALSE.

B-2.16.2 Set/Reset Latch

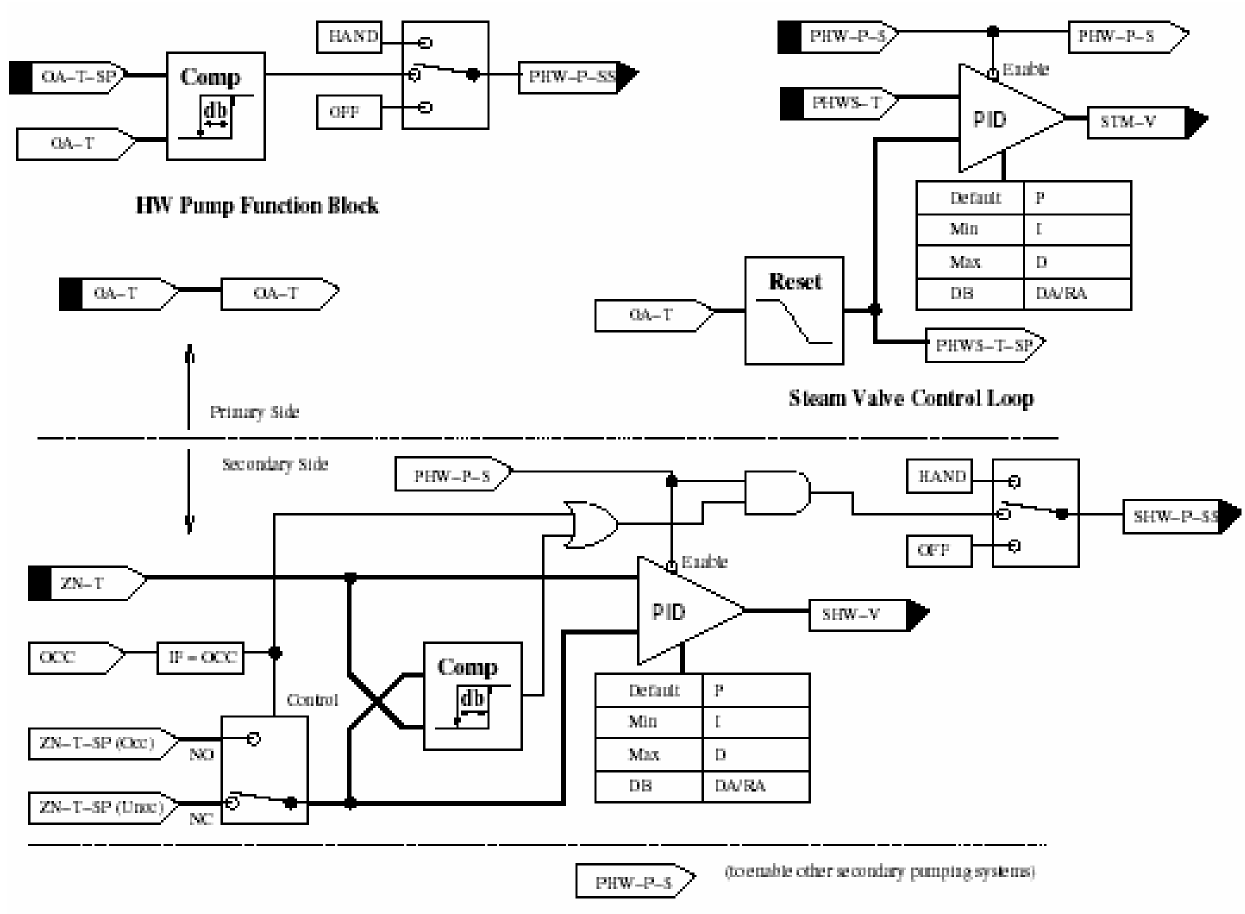
Picture not available at this time

This function block represents a latch. The latch has 2 binary inputs, a set input and a reset input, as well as a single binary output. Once set (by a TRUE value at the Set input), the latch's output remains TRUE until reset (by a TRUE value at the reset input). Likewise, once reset, the output remains FALSE until set by a TRUE value at the set input. Essentially, the latch remembers whether it was last Set or Reset.

B-3 EXAMPLE CONTROL LOGIC DIAGRAM

To better illustrate the interpretation and use of control logic diagrams, this section explains a sample control logic diagram for Central Plant Hydronic with Steam/HW Converter shown below in Figure C-2.

Figure C-1. Control Logic Diagram for Central Plant Hydronic with Steam/HW Converter



Examining the logic diagram we see that there are 3 main functional blocks, a hot water (HW) pump function block and a steam valve control loop on the primary side and a secondary control system functional block.

B-3.1 HW Pump Function Block

This block has one physical output, a Start/Stop signal to the Primary Hot Water Pump (PHW-P-SS). There may be other outputs from this block, signals that are available to other systems on the network. In addition, this block has 3 inputs:

- OA-T-SP: A hardware input; a Temperature SetPoint
- OA-T: A network input; Outdoor Air Temperature. OA-T is shown as a network input to the block. However, just below the block is a fragment which shows a hardware OA-T sensor which makes OA-T available on the network. This shows that the primary system must in fact have an OA-T sensor. This sensor could have been shown connecting directly to the this function block (see PHW-P-S in the steam valve control loop).
- A H-O-A switch on the output going to the PHW-P-SS

The OA-T and OA-T-SP signals feed a comparator with deadband. Assume that the deadband is set at 4 degrees and OA-T-SP = 64. Then, upon a drop in OA-T below 62 degrees the output of the comparator will be true. Upon a rise of OA-T above 66 degrees, the output of the comparator will be false. For OA-T between 62 and 66 degrees, the comparator will hold its current value.

The output of the comparator (ON when OA-T < 62, OFF when OA-T > 66) feeds the H-O-A switch. Note that there may be some hardware (a relay, for example) to interface the controller output to the H-O-A switch, since the H-O-A switch probably operates at 120 VAC. The output of the H-O-A switch controls the Primary Hot Water Pump.

B-3.2 **Steam Valve Control Loop**

This block has three outputs:

- STM-V: A hardware signal; a modulating control signal to the STeaM Valve
- PHW-P-S: A network output; Status of the Primary Hot Water Pump
- PHWS-T-SP: The SetPoint for Primary Hot Water Supply Temperature

This block also has 3 inputs:

- PHW-P-S: A hardware input; a Status signal from the Primary Hot Water Pump
- PHWS-T: A hardware input; the Temperature of the Primary Hot Water Supply
- OA-T: A network input; the Outside Air Temperature.

The OA-T signal feeds a reset schedule for the Primary Hot Water Supply Temperature SetPoint (PHWS-T-SP). This setpoint decreases as OA-T increases. PHWS-T-SP and PHWS-T feed a PID loop, which modulates the STeaM Valve (STM-V) to maintain PHWS-T at PHWS-T-SP. If the Primary Hot Water Pump (PHW-P) is off, the Status (PHW-P-S) will be false and the PID loop will assume its default value, which should result in STM-V being closed.

B-3.3 **Secondary Control System**

This control system has two outputs:

- SHW-V; a modulating hardware output to the Secondary Hot Water Valve
- SHW-P-SS; a hardware output; the Start/Stop signal to the Secondary Hot Water Pump (SHW-P)

In addition, there are 5 inputs:

- PHW-P-S; a network input indicating the Status of the Primary Hot Water Pump
- ZN-T; a hardware input from a ZoNe Temperature sensor
- OCC; a network input indicating OCCupancy status

- ZN-T-SP (Occ); a network input giving the ZoNe Temperature SetPoint for when the system mode is OCCupied

- ZN-T-SP (Unoc); a network input giving the ZoNe Temperature SetPoint for when the system mode is UNOCcupied

If the Primary Hot Water Pump is off, PHW-P-S will be false and SHW-V will be closed and SHW-P-SS will be off (unless overridden ON by the H-O-A switch). The Secondary Hot Water Pump (SHW-P) will be controlled by an H-O-A switch. The AUTO position will be ON if: PHWP-S is true and either the system is in OCCupied mode or the ZN-T is below ZN-T-SP (Unoc) (with a deadband)

The Secondary Hot Water Valve (SHW-V) is a modulating valve controlled by a PID loop which is enabled whenever PHW-P-S is true. When enabled, the PID loop will control SHW-V to maintain the ZoNe Temperature (ZN-T) at either the ZoNe Temperature OCCupied SetPoint (ZN-T-SP (Occ)) or the ZoNe Temperature UNOCcupied SetPoint (ZN-T-SP (Unoc)), depending on the value of the OCCupancy network input.

There may be additional secondary control systems, if so, the PHW-P-S signal will be available on the network for those systems.